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SKETCH OF THE GEOLOGY

SPITZBERGEN

BY

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38802

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The first notice of the geology of Spitzbergen is found in an appendix to the narrative[1]) of Sir Edward Parry's celebrated attempt to reach the North Pole, by crossing the ice North of Spitzbergen. In conformity with orders issued by the English Admiralty, enjoining the officers, when not engaged in the duties of the expedition, to devote all their time to scientific pursuits, they collected and brought home numerous specimens of rocks from the places they visited; and on this collection were afterwards based several, though rather incomplete, accounts of the geological features of the Northern coast of Spitzbergen. Amongst interesting objects brought home by Parry were some fragments of *Encrinites*, found among the calcareous strata at Cape Fanshawe.

In the same year (1827) Spitzbergen was visited by the Norwegian geologist Keilhau[2]), but in the narrative of his voyage the geological features of the country are scarcely mentioned. From Mount Misery on Beeren Island he however brought home a collection of fossils, which were afterwards examined and delineated by Leopold von Buch[3]) in a geological description of Beeren Island, based on the observations made by Keilhau. The

[1]) Narrative of an Attempt to Reach the North Pole in the year 1827, under the Command of Captain William Edward Parry. London 1828.

[2]) B. M. Keilhau. Reise i Ost- og West-Finmarken samt til Beeren Eiland og Spitsbergen i 1827 og 28. Christiania 1831.

[3]) L. v. Buch. Spirifer Keilhaui und dessen Fundort. Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin aus dem Jahre 1846. p. 65.

coal-strata of that island, most likely tertiary, are by v. Buch erroneously referred to the Coal-period.

Ten years later (1837) Professor Sven Lovén visited the Western coast of Spitzbergen, and among other places, Ice Sound, where he discovered several fossils belonging to the Mountain-limestone and the Jurassic formation, which until then had not been met with in so northern latitudes.

During the two following summers Spitzbergen was visited by a French Scientific Expedition on board the "Recherche" [1]; — Bel Sound in 1838, and the granite-region North of Magdalena Bay in 1839. The "Recherche", however, remained each time only a few weeks on the coasts of Spitzbergen, so that, notwithstanding the great resources of the expedition, the results of their geological researches were comparatively inconsiderable. Nevertheless Mr. Robert brought home a collection of fossils which were figured in the plates of the great work published on that expedition, and afterwards described by v. Koningk [2]. In the same work there are also some excellent views of the Western coast of Spitzbergen, which give a striking picture of those remote northern regions, especially interesting as an illustration of the origin and extension of the glaciers. Mr. Robert, too, ranged the strata containing *Spirifer* and *Productus* with the tertiary coal-bearing strata, and accordingly referred them both to the coal period.

In 1858 I visited, on board the yacht "Frithiof" hired and fitted out by Mr. Torell, Horn Sound, Bel Sound, Ice Sound, English Bay, Magdalena Bay, Amsterdam- and the Norway Islands, and made rich geological collections, among others, specimens of fossil leaves of different Miocene trees and plants.

In the same and the following year, Mr. Lamont [3] visited Spitzbergen, and from the interesting and lively account he gives

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[1]) Voyages en Scandinavie, en Laponie, au Spitsberg et au Feroë, sur la Corvette "la Recherche". Géologie, Minéralogie et Métallurgie par M. E. Robert. Livraison 4:e p. 87; 26:e p. 129. Géologie, Minérologie, Métallurgie et Chimie par M. I. Durocher. Livraison 29:e p. 469.

[2]) Bulletin de l'Académie Royale de Belgique. T. XIII (№ 6). T. XVI (№ 21.)

[3]) Seasons with the Sea-horses, by James Lamont. London 1861.

of his voyage, we find that he devoted some attention to the geology of the country. Mr. Salter afterwards published a description[1]) of the fossils brought home by Mr. Lamont, which were chiefly found at Bel Sound, and almost exclusively belonged to the Mountain-limestone. A few shells are also enumerated, belonging to the genera *Nucula* and *Aviculopecten*, but they could not be more definitely classified. They were found at Black Point near Deevie Bay, and most likely belong to the Jurassic formation.

When the last Swedish expeditions were undertaken, it was consequently known that the soil of the most arctic land consisted of strata formed at widely distant periods of the formation of the earth's crust, but it was impossible to arrive at any real knowledge respecting the geological structure of Spitzbergen from the scattered observations previously made. A vast field for more extensive researches was here opened to the Swedish explorers, whose attention had been especially directed by the commissioners of the Royal Academy of Sciences at Stockholm to a geological exploration of the country. In order to make this survey as complete as possible, every member of the party endeavoured to contribute to the extensive geological collections brought home from Spitzbergen, and deposited in the Riks-Museum at Stockholm. Besides that, a geologist who was to devote his attention chiefly to those pursuits, was attached to each ship engaged in the expeditions. Thus, in 1861, Mr. Blomstrand on board of the "Magdalena" visited and examined the North western part of Spitzbergen, between Sorge Bay and Ice Sound; Torell and myself, the North-eastern part between Sorge Bay, Seven Islands, Dove Bay and South Waijgats Islands. In 1864, during a forced stay of four weeks at Ice Sound, this bay which had already been visited by Mr. Lovén, myself and Mr. Blomstrand, was again explored, chiefly in boat-expeditions undertaken by Mr. Malmgren and myself. Later in the same year, visited Bel Sound, Horn Sound and Stor Fjord. The observation

[1]) Appendix to the above-mentioned work by Lamont.

made during the expeditions of 1858 and 1861, have already been published [1]) in the Transactions of the Royal Swedish Academy of Sciences, and I might therefore have given here a description merely of the geological features of the tracts visited during the expedition of 1864. But since the publication of these papers, some of the rich collections of fossils brought home by us, have been examined and described by Mr. Lindström [2]) of Visby, and Professor Osw. Heer of Zürich [3]); and thus for the first time it has been possible to give a description of the geological features of the coasts of Spitzbergen, comprising all the essential information we at present possess of those arctic regions. Instead, therefore, of confining myself to a description of the observations made during the expedition of 1864, I will give here the outlines of a geological map of Spitzbergen, illustrated by a sketch, as complete as possible, of the geology of that island.

Spitzbergen consists of five large islands, and a great number of minor ones, situated between 76° 26′ and 80° 50′ North latitude, and 10° and 26° longitude East from Greenwich. The two largest of these islands, West Spitzbergen and North-east Land have, like many other mainlands and large islands, the form of a triangle, the point of which extends towards the South. The same form seems also to characterize those peninsulas, into which the main-land is divided by the large bays that extend far into the country. By a glance at

[1]) C. W. Blomstrand. Geognostiska iakttagelser under en resa till Spetsbergen år 1861. Kongl. Vetensk. Akad. Handl. B. 4 № 6.

A. E. Nordenskiöld. Geografisk och geognostisk beskrifning öfver nordöstra delen af Spetsbergen och Hinlopen Strait. Kongl. Vetensk. Akad. Handl. B. 4 № 7.

[2]) Om Trias- och Jura-Förstenings från Spetsbergen af G. Lindström. Kongl. Vetensk. Akad. Handl. B. 6 № 6.

[3]) Oswald Heer. Om de af A. E. Nordenskiöld och C. W. Blomstrand på Spetsbergen funne fossila växter. Öfversigt af Kongl. Vetensk Akad. Förhandl. 1866. № 6.

the map we find that these bays have a most peculiar form, differing from that common in more temperate climes. They are everywhere almost equally broad and are most frequently divided, at a little distance from the entrance, into two arms of equal size, which suddenly terminate with a glacier or a low-land, without running into a narrow point; the shores are, except at the bottom of the bay, precipitous, and exhibit a fine section of the rocks of the country. Every thing seems to indicate that the bays and inlets of Spitzbergen are neither formed by a subsidence of the earth's crust, nor by the action of running water; but that they are either ancient glacier-beds, or have been excavated by powerful glaciers which, as the rock beneath was ground down and borne away, moved farther towards the interior, excavating the broad and deep slope, the bottom of which is now occupied by the sea. Frequently there is still a remnant of such a glacier at the bottom of the bay, as for instance, in Horn Sound, Kings Bay, Wijde Bay and other places. When no glacier is found at the bottom, the descent of the bay is generally continued towards the interior by an extensive and marshy low-land, which gradually, and without any such steep slope as is common along the sides of the bays, passes into the highland in the interior. We have here the bed of the névé which gave origin to the ancient glacier that once excavated the frith.

A similar formation of bays is undoubtedly still progressing on several parts of the coast as, for instance, North of the Rotges Mountains near Horn Sound. The mighty glaciers which here protrude into the sea, seem according to Dutch charts to have stretched as far as the low Dun Islands, the surface of which is in many parts polished by glaciers [1]). These islands are not marked

[1]) Though I had the opportunity of examining at several places in Spitzbergen old beds of glaciers surrounded by *solid* rocks, I have only very seldom met with any rocks polished and furrowed by glaciers; and those were besides always situated on the very edge of the sea. Such extensive and highly polished surfaces of rock as are every where met with in Scandinavia, are not to be found there. This evidently arises from the action of the frost which in connection with humidity will, in the course of only a few years, split the surface of the exposed rock. *The scored surfaces of rock in Scandinavia must therefore either have been formed beneath the surface of*

on the charts, although they were no doubt known to the Dutch, as being very rich in down, and situated in the vicinity of one of the most frequented harbours. The little sound, too, which unites Stor Fjord with Hinlopen Strait, has evidently been formed not long ago, probably by the decrease of those glaciers which descend at the North-east point of Barents Land.

There are, on the other hand, many circumstances proving that glaciers in other parts have, during the last centuries, advanced considerably as, for instance, at Horn Sound. That sound was apparently well known to the Dutch, as an old chart marks two anchorages there. They describe the sound as stretching one of its arms, containing two islands, somewhat Northward; but at present this arm is occupied by an immense glacier, and, excepting some small rocks, there are no other islands to be found in the bay. A similar case was noticed by Mr. Robert, at one of the arms of Recherche Bay (Bel Sound), and most likely analogous circumstances very much changed the shape of Stor Fjord, the bottom of which is occupied by an extensive and low glacier stretching in an even slope as far as Mount Chydenius. The large islands which, according to old charts, were situated at the inner extremity of the bay, cannot be the same small islets that are now to be found there; and it seems more probable that Mount Edlund, now encompassed by glaciers, and some other neighbouring mountain, similarly shut up by ice, were, at the time the whalers visited them, surrounded by water, and identical with those islands which on old charts are called Sea-horse Island and Seal Island. At Bel Sound I myself witnessed a most striking proof of glaciers, thus descending upon tracts hitherto free from ice. On the North coast of Bel Sound, directly to the East of the large island which separates Van Mijens Bay from the main bay, there existed, only a few years ago, one of the best harbours of Spitzbergen. The whalers on

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the water by floating ice mounts, or else in a more temperate climate, where the glaciers that originated on the heights of the mountains, stretch far beneath the snow line, and where consequently the rock, laid bare by the the melting of the glacier, is no longer exposed to such severe cold as in the arctic countries.

their way from the North coast to Stor Fjord, used often to anchor at this harbour in order to hunt reindeer in the neighbouring fertile valleys; and this, too, was one of the first places visited by Professor Torell's expedition in 1858. During this expedition I explored the surrounding country in all directions, so that on revisiting the place in 1864, I was able clearly to call to mind its former aspect. The shores of the harbour still in 1858 consisted of a broad strip of muddy land intersected by brooks, bounded to the West by high mountains, and to the North-east by a hill on which an old cross was erected over some grave. More to the East stretched, as far as Coal Mount, a marshy lowland traversed by a considerable stream. Directly above the banks of mire and gravel, composing the strip of muddy land which formed the shores of the harbour, gradually commenced a low but broad glacier (the "Frithiof Glacier"), which did not, as is usually the case with the glaciers of Spitzbergen, terminate with a break, and which was consequently considered by us as *a receding glacier*. In the banks of mire were found remains of various marine shells still covered with their epidermis, from which Mr. Torell suspected that these mounds of mud were not moraines, but had been recently forced upwards from the bottom of the sea by the glacier. During the winter of 1860—1861, the previously insignificant glacier descended upon the lowland and the grave-hillock on the shore, filled up the harbour, and extended far into the sea. It now constitutes one of the largest glaciers of Spitzbergen, from which immense blocks of ice constantly fall down, so that not even a boat can venture in safety beneath its broken border.

The glaciers on the Northern coast of Stor Fjord bear, in consequence of their low border and the strip of muddy land forced upwards before them, a great resemblance to the Frithiof glacier found at Bel Sound *previously to 1860;* and it therefore appears most probable that they still continue to advance, and possibly before long will fill up Ginevra Bay. This of course depends less upon the masses of ice at Spitzbergen increasing, than upon those masses of ice changing their course, as some-

times happens with rivers of unfrozen water. But wherever a glacier advances, it crushes the solid rock, and consequently contributes to the destruction of one of the most important conditions for its own existence, namely rocks or mountains that rise above the snow line; so that, should no other influences counteract the leveling action of the glaciers, it might be expected that the whole of Spitzbergen would within a very short period, geologically speaking, form one vast lowland, free from ice in the summer. The mighty denudation at Spitzbergen is however counterbalanced, to a considerable degree, by the rapidity, with which the land is rising; a rapidity which seems far to exceed that of the upheaval of land in most other parts.

If we compare the map of Spitzbergen published by us, with Dutch charts of earlier date as, for instance, that of Commodore Giles and Outger Rep, we are at once struck by a remarkable difference between them. To the North-west and South-west, the North-east Land extends in three peninsulas of considerable size, the extremities of which are in our map designated by the names North Cape, Shoal Point and Cape Sparre. All these peninsulas are covered with mountains of considerable height, which however have no connection with the highland of the interior, but are separated from it by low valleys. *These valleys are on old charts delineated as sounds, and in these sounds we often find rocks and glaciers marked;* which seems to indicate that the country was well known to the Hollanders and that their maps were based on real observations. An adjacent island situated between North Cap and Shoal Point, and most caracteristically named Low Island, is on these old maps delineated smaller than Moffen, though that islet, at least at present, is not a twentieth part so extensive as Low Island. All these discrepancies could be explained by assuming, that a considerable elevation of the North-eastern part of Spitzbergen has taken place since the middle of the 17th century.

Surer evidence of the upheaval which Spitzbergen has been undergoing during the last centuries, is however obtained

from the fragments of marine shells, bones of whales [1] &c., met with high above the present level of the sea, in many parts along the coasts of that island. Thus we already find Keilhau mentioning that he at Whales Point, far from the shore, and at a height of about 100 feet above the present level of the sea, discovered subfossil shells of the same species as those still occurring on the coasts of Norway. On the shores of Bel Sound, 39 metres above the surface of the sea, Robert examined some layers of earth containing shells of the genera *Mya*, *Tellina* and *Saxicava*. Lamont discovered at Bel Sound, 100 feet above the level of the sea, and at half an English mile's distance from the shore, a decayed vertebra of a whale, as well as the lower jaw of the same animal at Walter Thymens Strait at a height of 40 feet above the level of the water [2]. We too, along nearly the whole coast of Spitzbergen, *except the North-western part*, have discovered plain indications of an upheaval of land progressing in later times. Thus at Cape Lovén, on the Northern coast of North-east Land, we discovered along the shore a sandbank in which, at the height of 10 or 15 feet above the present level of the sea, were found some hafts of whale-harpoons, oars of a form different from that at present employed by the Norwegian sea-horse hunters, and other remains from the time the Dutch whalers used to frequent these regions. Bones of whales and immense masses of moss-covered driftwood were met with, 1—20 feet above the level of the sea, on the isthmus that separates the mountain tops of the Seven Islands; far in the

[1] The bones of whales, which are met with almost everywhere on the shores of Spitsbergen, have, no doubt, for the greatest part belonged to whales, killed by the whalers of the 16th and 17th century; and as the whale is too enormous an animal, to be drawn on the shore, these bones were originally imbedded in the sand or mud at least three or four feet beneath the surface of the sea. The quantities of whale-bones found on the shores of Spitzbergen some feet above the present level of the sea, are also the best proof of the upheaval of the land in historical time.

[2] In the Appendix to Lamont's Voyage we also find that a shell of *Buccinum glaciale* was discovered at Bel Sound at the height of between 400 and 500 feet. This shell was however most likely deposited by some seabird, so that the fact of its being found there, has nothing to do with the rise of the land.

interior of Low Island; at the Ryss Islands in Murchison Bay, and at many other places. Subfossil shells were collected at a great height above the surface of the sea on the Lime Shore and at Duym Point in Hinlopen Strait; on the West side of Safe Haven (at least 150 feet above the surface of the sea), and at Advent Bay in Ice Sound. Mr. Malmgren discovered a considerable part of the skeleton of a whale at Förvexling Point, at least 100 feet above the present level of the Stor Fjord. As the leveling action of the glaciers proceeds on a grander scale at Spitzbergen than at most other parts, so also that most important motive power of nature which acts in a contrary direction — that is to say the upheaval of the main land — may possibly there also work with unusual force. Still, whatever the final result may be of the struggle which is thus continually going on between the ice on the surface of the earth and the fire in its interior, it is certain that the exterior character of Spitzbergen will, during an almost endless course of years, remain but slightly changed.

With the exception of a few projecting mountain-tops, the interior of Spitzbergen at present consists of an immense ice-plateau, from 1500 to 2500 feet in height, which has its issue into the sea by means of the glaciers which everywhere on the coasts protrude into the sea. These glaciers correspond to the water-courses of more temperate climes, and therefore no rivers properly so called, are to be found at Spitzbergen, with the exception of some short, but often very abundant and rapid glacier-stream. Almost everywhere where no glaciers descend, the coast of Spitzbergen consists of high mountains, sometimes separated from the sea by a sandy lowland of a breadth from one to three Engl. miles. These mountains along the Western coast of the main-land and the Western shore of Stor Fjord, South of Agardh's Mount, shoot up into those numerous and pointed tops from which the name of this group of islands is derived; but on the South-eastern shore of Ice Sound, on the Eastern shore of Stor Fjord and at the Southern part of Hinlopen Strait, they form level plateaus which descend in a steep slope towards the sea. In consequence

of the scarce development of the vegetation, the slopes of the mountains are everywhere in these regions bare, except when covered by immense heaps of stones. Their structure is therefore discernible at a great distance from the sea; and such fine sections of rocks, as those which are everywhere to be found on the shore of Spitzbergen, are seldom to be met with in more Southern countries. This greatly facilitates the geological survey of this remote, and by geologists seldom visited land.

Excepting that range of mountains which forms Pr. Charles' Foreland, no other mountain ranges are met with at Spitzbergen. Evidently the whole country was once a single vast plateau, out of which, by the action of the ice, the isolated mountain-tops have been cut, which have given the island its name. The height of the mountains seldom exceeds 2000 or 2500 feet, and it is only at Pr. Charles' Foreland and at the peninsula South of Horn Sound, that a few tops attain a height of 4500 feet above the level of the sea. The difference in the contours and colours of the mountains manifests at once that they consist of various rocks possessing different powers of resistance against the destructive action of frost, rain and wind. Thus only the crystalline rocks, and the hard strata of slate and qvartzite of the Hecla Hook formation are sufficiently solid to form the pointed and rugged mountain-tops of the Western coast. The loose calcareous strata, underlying the Mountain-limestone, are easily recognized by low rounded heights covered with fragments of a grey limestone, and almost without any trace of vegetation; the upper strata of the Mountain limestone are characterized by tabular mountains with steep terraces; and the loose sandstone of the Triassic, Jurassic and Tertiary formations, by terrace-formed mountains with less precipitous slopes. A black or nut-brown girdle of equal breadth, stretching many miles at a fixed height above the level of the sea, denotes at once the presence of those plutonic rocks, which have given so peculiar a cast to most of the bays and sounds of Spitzbergen. The annexed map (Tab. II) shows in what great variety these different formations are found at Spitzbergen; and, therefore, in order to obtain

somewhat complete sketch of the geological structure of this group of islands, it will perhaps be necessary to describe more particularly each of these formations.

I. Crystalline Rocks.

The Northern, North-western and probably also the North-eastern and Southern parts of Spitzbergen contain crystalline rocks. They consist of:

A. *Granite-gneiss.* Granite is found in many places at Spitzbergen as, for instance, between Bird and Brandywine Bay, at Cape Lindhagen and Norway Islands etc.; but it always gradually passes into stratified gneiss, so that real granite does not seem to exist there to any great extent. The strata of gneiss generally stretch Northward and are almost vertical, often alternating with beds of granular limestone, in which are found nearly all those minerals (*chondrodite, spinell, wollastonite, idokras, hessonite, serpentine*, etc.) that are peculiar to the crystalline limestone strata of Finland and Sweden. In many parts, especially on the shores of Parry's Island, the gneiss strata are intersected by veins of pegmatite, consisting of a coarse grained mixture of *orthoclase, quartz* and *mica*, in which we founds several minerals not occurring in the other granite as, for instance, *tourmaline* and *orthite*. These coarse-grained masses often form narrow veins, surrounded on all sides by gneiss, without any connection with underlying rocks. The foreign minerals are mostly crystallized along the very irregularly formed walls. Besides this, these veins are mostly so narrow that in consequence of the chilling influence of the walls, a molten eruptive mass would have cooled long before it could have filled up the fissure now occupied by pegmatite. Thus those granite veins seem either to be fissures *filled from above*, or to have been formed by a local change in the surrounding rock, most likely produced by infiltration of mineral water.

B. *Crystalline schists.* By alternating strata of gneiss and crystalline-limestone the granite gneiss gradually passes

into the crystalline schists, which are especially developed on the Eastern shore of Wijde Bay. The strata are there almost vertical, stretching from N. to S., and consist of hornblende-schist and qvartzite, alternating with talcose- or mica-schist, and a kind of petrosilex or feldspar-porphyry. Two profiles drawn by Mr. Blomstrand [1]) of the rocks at Mussel Bay and Aldert Dirkses Bay, present a faithful picture of the variation of strata, characterizing the rocks on the Eastern shores of Wijde Bay; the careful study of which would undoubtedly afford much important information respecting the mutual relation of the plutonic and metamorphic rocks. According to Mr. Blomstrand, parallel beds are found at Mussel Bay consisting, within a space of 100 feet, of: slaty qvartzite; fine crystalline hornblende-schist; granite with specular-iron and palegreen talc; and a close grained rock, with crystals of feldspar, a kind of feldspar-porphyry.

Judging from the gravel and boulders which are dispersed along the Western shore of Wijde Bay, and often form the principal mass of old moraines, rocks of granite and gneiss are also to be found farther in the interior of the country, South of Wijde Bay. The high mountain ranges of Horn Sound, also, probably consist of gneiss.

The crystalline schists of Spitzbergen are everywhere almost vertical, with folds so often alternating, as to render it impossible to determine even approximately the thickness of the measure.

2. Hecla Hook formation.

Next to granite-gneiss, thick sedimentary strata are met with, which I have called after the mountain Hecla Hook where they are found most developed. These strata, probably belonging to the Silurian or Devonian periods, are very abundant at Spitzbergen, and remarkable for the total absence of fossils; a circumstance so much the more astonishing as the

[1]) See the above mentioned memoir by Blomstrand. p. 11—13.

fine strata of slate and limestone which constitute this formation, appear most suitable for the preservation of organic remains.

The layers of the Hecla Hook formation usually stretch N—S, and are much dislocated and folded; so that it was very difficult to determine the relative age of its beds, namely:

1. (Lowermost.) Grey limestone intersected by white veins of qvartz and calcite. At the Northern shore of Cape Wrede, Hecla Hook, Cross Bay, English Bay, Dödmanden, the rocks off Middle Hook in Bel Sound, and the southern part of Beeren Island.

2. Very compact qvartzite, of white, grey or reddish colour, consisting of qvartzgrains, seldom intermixed with mica. At Cape Irminger, C. Lovén, C. Wrede and C. Platen, Low Island, Hecla Hook, Cross Bay, English Bay, a rock North of Cape Staratschin, the mountains North of the entrance to Bel Sound and Dun Islands North of Horn Sound.

3. Dark, grey or reddish-brown, often beautifully striped clay-slate. Cape Irminged, C. Lovén, C. Wrede, C. Platen and C. Hansteen, Low Island, the Northern shore of Murchison Bay, Hecla Hook, Nord Fjord, Klaas Billen Bay, and the mountains in the glacier North of Horn Sound.

The sections on the map show the stratification of these beds at most of the above enumerated places, and it is unnecessary to give here a more detailed description.

I have also marked on the map, with the yellow colour of the Hecla Hook formation, some other very ferrugineous, reddish brown beds of sandstone, limestone and a puddingstone consisting of pebbles of the Hecla Hook strata 1—3, cemented by a ferrugineous sandstone. These beds (*Red Beach* strata), which are discernible from a great distance by the reddish colour assumed by the waters of the intersecting rivers, are met with at Red Beach on the Western shore of Wijde Bay and Lomme Bay, and the Northern shore of English Bay. But only at the latter place have I determined the stratification, which shows that those schists lie between the qvartzite beds of the Hecla Hook formation and the Mountain-limestone. One meets here in ascending order:

Crystalline Schists and Hecla Hook Strata.

1) (on the shore) Mica schist.

2) Grey magnesian limestone.

3) Quartzite, white or grey, very compact, and alternating with small beds of limestone.

Red Beach Strata:

4) Red sandstone.

5) Reddish brown, argillaceous limestone.

6) A loose, red puddingstone.

Strata probably belonging to the same age as the beds on the islands in Murchison Bay (Ryss Island strata):

7) A breccia of angular flint fragments, united by a grey calcareous cement, and covered with argillaceous limestone.

These strata lie N.W.—S.E. with an almost perpendicular dip to *South-west*, so that the oldest of them, the mica schist, seems to cover the younger Hecla Hook and Red Beach strata.

According to Mr. Blomstrand, the mountains on the Western shore of Wijde Bay also consist of Red Beach strata, namely of reddish brown sandstone, alternating with strata of green or grey micaceous sandstone, and beds of a plutonic rock, different from the common hyperite of Spitzbergen.

3. Mountain-Limestone.

The red and green ribboned slate on the Northern shore of Murchison Bay and Klaas Billen Bay is covered by strata, easily recognizable wherever they occur, and called by us Ryss Island strata. Probably these strata belong to the Mountain-limestone, at least they have a very striking resemblance to some overlying strata containing corals, belonging to this formation.

They almost exclusively consist of a dusky, yellowish magnesian limestone, devoid of fossils, and only indistinctly or scarcely at all stratified, of such a peculiar coralline structure that at first sight one would presume it to be intersected in all directions by coral-stems; which, however, is probably not the

case. Often this limestone alternates with small beds of qvartzite and flint, also devoid of fossils, but resembling the flintbeds of the overlying Mountain-limestone. The most sterile tracts that we met with at Spitzbergen consist of beds belonging to this formation, which is developed at Shoal Point, the islands in Murchison Bay, the peninsula between these and Wahlenbergs Bay, Drift-wood shore in Lomme Bay, and the Northern shore of Klaas Billon Bay. On the limestone the parallel-structure is scarcely discernible, and the difficulty of determining its stratification would therefore be great, were it not now and then interrupted by strata of siliceous rocks; the exposed, hard, and compact ridges of which have undoubtedly proved a requisite shelter against the advancing sea, to more than one of the Ryss Islands in Murchison Bay. The rocks occurring in these more compact layers, are of two kinds, viz:

1) Compact, completely homogeneous black or darkbrown flint, in which no traces of fossils were found, although its exterior bears much resemblance to certain fossiliferous strata at Axel Islands in Bel Sound.

2) A mixture of flint and limestone. The flint here takes the form, partly of round bullets, partly of cylinders from 1/8 to 1/4 of an inch in thickness; the intermediums being filled up with grey limestone in which frequently small cavities occur, containing crystals of qvartz. These cylinders are often repeatedly branched, and bear such a striking resemblance to coral stems, that only the absence of organic structure forbids the supposition, that these strata constitute remains of old colonies of corals.

3) A yellowish qvartzite, similar to the qvartzite of Hecla Hook. All these strata are on the Ryss islands almost perpendicular, and their strike is N. and S.; on Drift-wood shore, in conformity with the underlying Hecla Hook strata, N.N.W. and S.S.E., with a dip of above 60° to E.N.E.

The Ryss Island limestone is, on the Eastern shore of Lomme Bay, covered with: 1) Red and white sandstone, bearing indistinct traces of impressions of fucoid plants. 2) Grey-lime-

stone with numerous, but badly preserved fossils (small species of *Cyatophyllum*, *Terebratula*, *Productus*, and stalks of *Encrinites*, etc.), in certain respects allied to, though not identical with, the fossils from Mount Lovén and Mount Angelin. 3) Limestone with nodules of flint and numerous cavities, filled with crystals of *calcite*. The Western shore of Lomme Bay presents a fine profile of these strata, showing that they lie tolerably horizontal, with a slight dip to the East.

On the Northern shore of Klaas Billen Bay, the red and green slates of the Hecla Hook formation are also covered with beds, first of Rýss Island limestone, and then, of very similar limestone abounding in fossils, *especially corals*, somewhat resembling those met with at Cape Fanshawe. The same fossils, too, occur in Kings Bay, and on the Northern shore of Bel Sound, directly to the West of the entrance to Van Mijens Bay, where they are imbedded in limestone of a grey colour, both when newly broken, and when eroded by the atmosphere. These strata (Cape Fanshawe strata) constitute the lowest beds of the Mountain-limestone at Spitzbergen.

The limestone strata at Cape Fanshawe are covered with a layer of hyperite which more to the South sinks to the level of the sea, thus separating by two mountains, Alkfjället and Duym Point, the coral layers at Cape Fanshawe from the upper range of the Mountain-limestone, which forms almost horizontal strata of sandstone, limestone and flint, more than 1500 feet in thickness, and loaded with fossils. The sandstone seems to constitute the underlying part of the formation; above it one meets limestone; then, thick beds of flint alternating with limestone. But as the mountain slopes are covered with immense and precipitous heaps of loose stones, from which only here and there outcrops are visible, it is very difficult, from a superficial examination, exactly to determine the stratification of these beds characterized almost the same kinds of fossils belonging to the genera *Spirifer*, *Productus*, and *Terebratula*. In former times these strata stretched across Hinlopen Strait to Angelin Mount which consists of exactly the same strata as Mount Lovén; but the loose

limestone and sandstone have, when not sheltered by the more solid beds of hyperite, been ground down and washed away by the glaciers and the sea.

In Ice Sound, too, strata occur belonging to the upper range of Mountain limestone, namely:

On the Eastern shore of Safe Haven: Perpendicular strata of clay-slate and hard siliceous limestone, loaded with shells of *Productus, Spirifer* etc. Strike N. and S.

On the Southern shore of the main bay, West of Cape Staratschin, and at the inner extremity of Green Harbour: Greatly disturbed and folded strata of the same kind as those at Safe Haven. The prevailing dip is here East, at an angle of 50° to 60°.

At Gyps Hook, between Sassen Bay and Klaas Billen Bay: Horizontal strata abounding in fossils, and formed of: a) loose grey limestone with *Spirifer, Productus* etc.; b) beds of grey limestone and grey gypsum with nodules of alabaster, resembling, when viewed from the sea, strings of pearls; c) a hard siliceous slate, of the same kind as the rock at Axels islands in Bel Sound; d) Hyperite.

Skans Bay: Similar strata of grey limestone, and of grey and white gypsum also occur at Skans Bay, on the Northern shore of Klaas Billen Bay. Here the strata slightly incline towards the West, and are covered, first, by beds of hyperite; and then, at Saurie Hook, by strata belonging to the Triassic formation.

Following the North shore of Bel Sound from West to East, and commencing from the third mountain West of the entrance to Van Mijens Bay, we meet with:

1) Vertical strata (strike N. and S.) of white, extremely hard sandstone, alternating with rather narrow strata of darker sandstone. East of this sandstone which is altogether devoid of fossils, and occupies the most Western of the three mountains West of Frithiof's Glacier, we find, first, as may be presumed from stones that have rolled down from the heights, a thin stratum of hard, siliceous conglomerate, and then:

2) *Cape Fanshawe strata.* Very hard, grey limestone, containing shells of *Euomphalus, Productus,* stems of *Cyato-*

phyllum, spines of *Echinoids* etc. The middlemost of the three mountains West of the glacier, consists almost entirely of these strata, containing similar fossils to those from Cape Fanshawe and the lower fossiliferous strata on the Northern shore of Klaas Billen Bay.

3—5. *Strata belonging to the Upper Mountain-Limestone, viz:*

3) Loose, grey limestone, consisting almost entirely of fine, well preserved fossils, belonging to the same species, especially of the genus *Spirifer*, as the fossils of the grey limestone of Mount Lovén and Mount Angelin. On the shore, together with this limestone, fragments of a very peculiar breccia are met with, consisting of angular pieces of white limestone, mixed with pebbles, and bound together by a kind of grey cement. The limestone fragments enclosed in the breccia, are angular, very loose, and resembling chalk. They were perhaps formed by the same eruption of hyperite which at Bel Sound, also, broke through the sedimentary formations, and now composes one part of the mountain at the entrance of the Bay; and which, also, in the form of a black, horizontal stratum, constitutes the upper brow of the inner ridge. Between the strata 1 and 2, a few small beds of stratified qvartz already occur, which, however, seem to be altogether devoid of fossils; but it is first to the East of the limestone strata, that these qvartz masses are found in somewhat larger quantities, forming the fourth range of this measure, viz:

4) More or less pure, stratified, dark flint containing *Productus*, *Spirifer* etc. These strata, remarkable for the abundance of fossils they contain, are extremely compact and hard, so that it is with the utmost difficulty specimens can be got of the fine, large fossils occurring there. On the islands which block up the opening of Van Mijens Bay, a most beautiful section of these qvartz strata may be seen. Their strike is about N. and S.; they being for the most part quite vertical; sometimes, especially on the inner side of the island, with a precipitous dip to the East. These strata may be divided into two distinct beds, viz: a)

A mixture of flint and limestone, most compact and hard to break; being grey and quite homogeneous when newly broken, but assuming a rugged, yellowish brown appearance by long exposure to the atmosphere. b) Black flint, but very little affected by the influence of the atmosphere. The fossils (especially *Productus* and *Spirifer*) of these two beds, of which the one (a) occupies the greater part of the island, and the other (b) a narrow ridge on the East side, are perfectly identical.

5) Reddish brown sandstone, with a steep dip to the East, bearing traces of fucoïd plants, and covered by a slate impregnated with mica, in which, also, are found badly preserved impressions of plants. These strata, probably belonging to the Triassic formation, form the ridge on the Western border of Frithiof Glacier. From here, a level ground over which this glacier has now descended, stretches as far as Coal Mount. Only here and there on this lowland, directly below, and West of the glacier, outcrops are met with, showing that the rock still consists of black slate or grey sandstone, both devoid of fossils, with the exception of a few indistinct impressions of plants. The strike of the strata is North and South with a precipitous dip, partly to the East and partly to the West; and sometimes they are quite folded. On the shore East of the glacier, a small, very craggy rock descended [1]) into the sea, which, from its position, one would presume to consist of the same sandstone that constitutes the rocks on the lowland. This, however, is not the case; for here we meet with strata, dipping only 12° Northwestward, and formed of black, bituminous slate, with fossils of the genera *Pecten* and *Ostrea*. Farther down on the same rock the strata are interspersed with black nodules containing *markasite*, by the oxidation of which the surface of these beds had assumed a whitish appearance. These strata are probably referable to the Jurassic formation, although the fossils were so badly preserved that it was impossible fully to identify them with any of the Jurassic fossils from Ice Sound or Stor Fjord.

[1]) At present this rock is covered by the Frithiof Glacier.

At the inner part of Recherche Bay, Mr. Robert, during the French expedition of 1838, met with strata of magnesian limestone, loaded with fossils, and which he referred to the Mountain-limestone; but Mr. v. Koningk afterwards described them as belonging to the Permian formation. The engravings by Mr. Robert in the atlas of the French Expedition (Atlas Géologique), seem, however, as far as we can judge from the badly designed figures, to prove that these fossils are identical with those in the Mountain-limestone at Ice Sound and Hinlopen Strait.

Mr. Blomstrand met with Mountain-limestone fossils on the South-western shore of Kings Bay, viz: a) in the outermost mountain near Quad Hook, limestone with *Euomphalus*, *Cyathophyllum* etc. *(Cape Fanshawe strata);* b) in a small rock, or a large boulder, between that mountain and the sea? limestone loaded with fossils, especially *Productus*, of the same species as the fossils from Axel Islands in Bel Sound.

By what is above mentioned, we find that the Mountain-limestone is widely spread over Spitzbergen, and that the whole group of islands was during that period submerged; no remains of land plants or coal-beds occurring in these beds. Mr. Robert, it is true, who assumes that the coal-beds of Spitzbergen belong to the carboniferous age, gives some imperfect drawings of a *Lepidodendron* and a *Calamites* or *Sigillaria*, found at Bel Sound; but, as will be seen farther on, these statements must be considered altogether erroneous, as the coal-beds of these high northern tracts are referable to a period far more recent than that of the carboniferous plants.

The description of the fine and numerous fossils (about 100 species), collected from the Mountain-limestone at Spitzbergen, will soon be completed by the able palæontologist Professor Angelin, and will, no doubt, throw an important light on the Polar fauna of that age.

4. Permian Formation.

As we mentioned above, the fossils collected by the French Expedition, and described by Mr. v. Koningk, did not belong to the

Permian formation, as v. Koningk states, but to the Mountain-limestone. Mr. Salter [1]) mentions on the other hand, that he recognized in a detached block found by Mr. Lamont on the Thousand Islands, real Permian fossils, viz: *Spirifer alatus*, Schlotheim., an ordinary *Zechstein* fossil, a small *Productus* (v. Koningk's P. horridus), and a large foliaceous *Stenopora*. Mr. Lamont supposes that this detached block had come from Giles Land. It appears, however, more likely that it had originally belonged to some nearer strata which once covered the hyperite of Thousand Islands, and which, probably, are yet to be found at Stansforeland. Real Permian strata seem, consequently, to occur at Spitzbergen, although probably not to a very great extent.

5. Trias.

This formation is most developed on the promontory dividing North Fjord from Klaas Billen Bay, a place several times visited by the Swedish expeditions; first by Mr. Bomstrand and Mr. Dunér in 1861, and then at two different times by myself, Mr. Dunér, and Mr. Malmgren, in 1864. It constitutes also for the geologist one of the most interesting parts of the whole polar region.

On the Northern shore of Klaas Billen Bay, the flint and gypsum strata of the Mountain-limestone are covered by a bed of hyperite which, somewhat West of Skans Bay, sinks down to the sea, and farther Westward is covered by black calcareous slate alternating with limestone of a grey colour when newly broken, but yellowish, after being exposed to atmospheric influence. These strata contain only a few fossils which, although imperfectly preserved, nevertheless at first sight show that these beds belongs to a period altogether different from the Mountain-limestone.

The shores of Cape Thordsen exhibit a profile of the lowest beds of this formation. Proceeding from the South side of Cape Thordsen Northward, a vast, gradually ascending low-

[1]) Seasons with the Sea-horses by James Lamont. London 1861. Appendix.

land must be crossed, which is partly strewed with detached hyperite blocks, partly consists of craggy outcrops of the same rock. This bed of hyperite is covered, first, by black bituminous limestone-slate, and then, by grey sandstone and limestone, in which colossal nodules of yellow limestone are imbedded, and over which, on the Northern side of Reindeer Valley, stretches another, smaller bed of hyperite. A great number of fossils were collected during the Swedish expeditions of 1861 and 1864 from the strata enclosed between the last mentioned bed of hyperite, and that which surmonts the Mountain-limestone. These fossils have been examined by Mr. G. Lindström who, in the Transactions of the R. Swedish Acad. of Sciences, has described the following species:

Nautilus Nordenskiöldi, Lindström. This large species of *Nautilus* occurs in great abundance in the limestone nodules which are interspersed in the sandstone at Saurie Hook, on the south side of Reindeer Valley.

Nautilus trochleaeformis, Lindström. Only one specimen was met with, enclosed in the above mentioned nodules of limestone.

Ceratites Malmgreni, Lindström. Together with the former species at Saurie Hook.

Ceratites? Blomstrandi, Lindström. At Middle Hook[1] in Ice Sound. (Blomstrand.)

Ceratites laqueatus, Lindström. Interspersed in the limestone nodules of Saurie Hook.

Ammonites Gaytani, Klipst. var? In the limestone nodules of Saurie Hook.

Possidonia? Some shells of a species probably belonging to this genus were found by Blomstrand in the hard rock at Middle Hook.

[1]) I have retained the name used by Blomstrand, of the mountain or rather the plateau, situated North of the extensive valley (Reindeer Valley) crossing the peninsula that separates North Sound from Klaas Billen Bay. The mountain South of the valley is marked on the map with the name of Saurie Hook.

Halobia Lommeli, Wissmann. Very common both at Saurie Hook and Middle Hook. This species occurs, too, at Cape Lee.

Halobia Zitteli, Lindström. Like the *H. Lommelii*, innumerable masses of this species form beds of slate, as thick as 3—5 inches, at Cape Thordsen. The shells of the young often constitute the entire mass of the slate; and at a hasty glance they might be mistaken for *Entomastraca*. The same species occurs in a somewhat thinner slate at Middle Hook. (Blomstrand.).

Monotis? A species approximating to *M. Alberti*, Goldf., occurs at Middle Hook. (Blomstrand.)

Monotis filigera, Lindström. Numerous, though incomplete specimens, occur in the slate at Saurie Hook.

Forms of *Pecten*, *Lingula* and *Encrinus*, which cannot be fully determined.

The most interesting fossils in this formation are, however, the jaws, vertebra, ribs etc. of vertebrate animals, which I met with, principally, at Saurie Hook, during the expedition of 1864. These fossil bones are imbedded in the grey slate and brown bituminous coprolitic limestone forming the upper stratum of that mountain; and are found both in the fast rock and the detached blocks that have rolled down along the sides of the mountain. The bones have occasionally been transformed into *turkois*, or have at least assumed the blue colour of this mineral. They have belonged to several species; among which may be distinguished remains of one or more species of fishes, and of some *Ichtyosaurus*.

The whole Eastern side of Stor Fjord is formed of almost horizontal strata, consisting, to a great extent, of grey sandstone with few fossils, or of black clay-slate. These strata are bounded by two layers of hyperite, of which the underlying one, exposed at many parts along the coast from Thousand Islands up to Edlunds Mount, rises only very little above the surface of the sea, but the other one forms a steep stratum of equal thickness near the top of the mountains, and is

surmounted by a sandstone resembling the underlying stratum. Judging from the fossils found at Whales Point and Cape Lee — among which several specimens of *Halobia Lommelii* and a *Saurie vertebra* resembling corresponding fossils from Saurie Hook — all these strata, measuring about 1200 feet, and being mostly devoid of fossils, belong to the Triassic formation.

In a detached stone at Exmouth Island (Polar America, 77° 12' N. lat. 96° long. W. from Greenw.) Sir Edward Belcher found some fossils which, judging from the figures in the account of Sir Edw. Belcher's voyage, bear a striking resemblance to the fragments of bones met with at Saurie Hook; and it seems most likely that the bones from Exmouth Island, not accompanied by other determinable fossils, belong to the same formation as the Saurie strata of Spitzbergen, and not to the Jurassic period, as has hitherto been assumed. The Triassic formation seems, also, to be of considerable extent, not only at Spitzbergen, but within the whole of the polar region.

6. Jura.

Following the Southern shore of Ice Sound from West to East one first meets qvartzite, with Brachyopoda belonging to the Mountain-limestone, and then very folded strata of clay-slate, grey limestone, and sandstone, in which only a few fossils, belonging to the Jurassic formation, are found. The clay-slate is at many places filled with large spherical concretions, sometimes of a diameter exceeding two feet. On the other side of Green Harbour, between this bay and Sassen Bay, the same strata occur, but they are here quite undisturbed and horizontal, and, at a height of a few hundred feet, covered with Miocene sandstone. Close to the surface of the sea one here meets black clay-slate, alternating either with grey limestone or hard sandstone; the beds of limestone being now and then separated, like strings of pearls, in round calcareous nodules. Among the scarce fossils of these strata *Bivalves* are most common; but at some places, too, one finds badly preserved impressions of *Cephalo-*

phoda. Along the shore between Advent Bay and Sassen Bay, immense, angular blocks of a hard, coarse-grained conglomerate, are scattered in the sea. These blocks have evidently rolled down from a bed of conglomerates projecting precipitously near the brow of the mountain, and probably separating the Jurassic strata from the Tertiary ones; its age being most likely the same as the conglomerate beds at Middle Hook in Bel Sound.

On the Western shore of Stor Fjord, at Mount Agardh, there are, also, strata belonging to the Jurassic formation, and abounding in fossils which, however, are in bad preservation. The base of this pyramidical mountain, 1500 feet in height, consists of an extensive plateau rising in a steep strand terrace 30 to 50 feet above the surface of the sea. When we visited this place, the plateau was altogether free from snow; quite dry, and paved with the most complete evenness and regularity, with small round stones or pebbles of from half an inch to an inch in diameter, and for the most part formed around fragments of *Belemnites*, or some other shell belonging to the Jurassic formation. Many of these *Belemnites* or shells have subsequently been eroded, so that a conic or spiral hole has been produced in the otherwise round pebbles. Above this remarkable plateau one meets with:

1. A thick bed of loose, black, pyritiferous limestone-slate containing *Belemnites* in abundance, and some few *Bivalves*, of which we however were not able obtain a single specimen, the slate being so very brittle. This pyritiferous slate resembles greatly that of the Grave Hillock, now covered with ice, on the Northern shore of Van Mijens Bay.

2. A small, and extremely fossiliferous stratum of grey, ferruginous limestone, which may easily be perceived, even at a distance, by the red colour it has assumed through atmospheric influences.

3. A stratum of hard sandstone, extending to the top of the mountain, and containing but very few and badly preserved fossils. Near the top of the mountain a small bed of hyperite alternates with the sandstone.

Already in the year 1837, Mr. Lovén brought home some fossils from Cape Staratschin West of Green Harbour in Ice Sound, which show that strata belonging to the Jurassic formation really occur in these high Northern latitudes. In 1858, I collected similar fossils from different places between Green Harbour and Advent Bay; in 1861, Mr. Blomstrand also collected some at the same places[1]); and in 1864, I brought home Jurassic fossils, from the coast between Coal Bay and Advent Bay, the southern shore of Sassen Bay (about one or two miles N.W. of the Hyperite Hat), and Mount Agardh. However, the fossils in the Jura of Spitzbergen are very scarce, and in a bad state of preservation, and it was consequently very difficult to determine them. We are indebted to Mr. G. Lindström for this laborious work; and from his treatise, published in the Transactions of the Academy of Sciences, I will here enumerate the most important species found by us.

Ichtyodorylithes. Various fragments of fishes have been met with in the sandstone at Advent Bay and Sassen Bay.

Serpula. Numbers of broken, irregularly formed tubes, occurring at Advent Bay and Sassen Bay, probably belong to this genus.

Ammonites triplicatus, Sow. Impressions of this species were met with at Sassen Bay in a black slate which was extremely brittle, from its intermixture with oxided *pyrite*.

Other not determinable fragments of *Ammonites*, belonging to the group of *falcifera*, were found at Advent Bay and Cape Agardh; at the latter place they were interspersed in some of the globules of sandstone at the foot of the mountain.

Belemnites of the group *Arcuati*, at Green Harbour (Lovén), interspersed in limestone; and at Cape Agardh. Here the Belemnites occur in great number in the black slate which forms the lower part of the mountain. All the specimens were,

[1]) From the strata at Grey Hook Blomstrand, also, collected some fossils *probably* belonging to the Jurassic formation. They were, however, too indistinct to be definitely determined; and the age of these strata is, therefore, not fully decided.

however, greatly eroded by salts formed by the oxidation of the *pyrite* interspersed in the slate.

Dentalium. Fragments of species belonging to this genus are met with at Advent Bay and Cape Agardh. They may perhaps belong to the *D. Moreanum*, d'Orb.

Panopaea. On the Western shore of Advent Bay Mr. Blomstrand met with a stone kernel, perhaps belonging to the *P. peregrina*, d'Orb.

Tellina. The impression of a left shell, discovered at Advent Bay, resembles the *Tellina Zeta*, Qvenst.

Cytherea. A stone kernel, found by Professor Lovén in the rocks at Cape Staratschin, may possibly belong to this genus.

Cyprina inconspicua, Lindst. Slightly resembling the *C. Syrolla* of Petschora. Found in abundance at Cape Agardh and in the dark limestone at Sassen Bay.

Cardium concinnum, v. Buch. At Advent Bay (Blomstrand) and the top of Cape Agardh.

Solenomya Torelli, Lindstr. Found by Mr. Blomstrand at Advent Bay.

Nucula. An impression of a left shell from Advent Bay, approximating to the *Nucula Hammeri*, Defr.

Leda nuda, Keys. Common at Advent Bay.

Inoceramus? revelatus, Keys. Common at Cape Staratschin and Advent Bay.

Ancella Mosquensis, v. Buch var. At Cape Staratschin (Lovén), Sassen Bay, and Cape Agardh. In the sandstone at Advent Bay Mr. Blomstrand also discovered numerous impressions of another, probably new species, of this genus.

Pecten Demissus, Bean. Common in the strata at Advent Bay, and between Advent Bay and Coal Bay.

Pecten validus, Lindstr. Very common in the ferruginous limestone at Mount Agardh.

Ophiura Gumaelii, Lindstr. On the East shore of Advent Bay (Blomstrand).

Besides this, there are in the specimens of rocks brought home, shells of at least fifteen species of bivalves, most likely

belonging to the genera *Arca*, *Nucula*, *Avicula* etc. Gasteropoda, are, however, scarce; fragments, only, of shells and kernels having been met with. Fragments of wood, and impressions of algæ are also found in these strata. But the fossil wood that is found on the shore between Cap Staratschin and Green Harbour, and those broad algous forms which give a black colouring to the sandstone at the last named bay, do not belong to the Jurassic, but to the Tertiary formation.

The measures of the Jura may be divided into two groups, both with regard to their position, and the fossils they contain, viz:

1. An older group, the stratifications of which are often disturbed. To this belong the strata underlying the hyperite at Mount Agardh; and the Jurassic strata on the Western shore of Sassen Bay, and at Cape Staratschin.

2. A younger group, the stratifications of which almost always are quite undisturbed. To this belong the strata extending from the Western shore of Green Harbour to Sassen Bay, and probably also beyond the hyperite at Cape Agardh.

The following table will show the distribution of the most important fossils between these two groups — the occurrence of a species being marked by a cross.

	Belemnites.	Aucella mosquensis.	Cyprina inconspicua.	Ammonites triplicatus.	Inoceramus revelatus.
Cape Staratschin	+	+	—	+?	+
Sassen Bay	—	+	+	+	—
Cape Agardh	+	+	+	+?	—
Advent Bay	—	—	—	—	+

Thus, of all the six or seven species found in the Jurassic formation at Advent Bay, there is only a single one identical with the fossils found at the other places.

With regard to the position occupied by the Jura of Spitzbergen in the great Jurassic epoch, Mr. Lindström shows that these Northern strata correspond most nearly to the Ju-

rassic strata at Petschora, and the two upper strata at Moscow; but that only a few West European species have been met with at Spitzbergen.

7. Hyperite.

The youngest formation in which hyperite [1]) occurs at Spitzbergen, is the Jurassic; and I will therefore, before proceeding to the description of the Tertiary formations at Spitzbergen, in a few words mention this rock occurring in such immense masses in many parts of the polar regions, and giving so peculiar a cast to the tracts where it occurs. The hyperite of Spitzbergen bears almost without exception the same aspect [2]), so as to render it impossible to discover, whether a piece of the rock in question be taken from the layers underlying the granite at Brandywine Bay, or from the Jurassic strata at Cape Agardh. It consists of an even and rather fine grained, darkbrown mixture of greyish green *labrador*, *hypersthene*, and *specular iron* or *ilmenite*. Its structure is everywhere a massy one, excepting where it has assumed the columnar form peculiar to basalt, so that the rock generally is extremely tough and not easily broken. From exposure to the atmosphere hyperite assumes a rusty brown aspect; and the hyperite beds that often interstratify the sedimentary layers, may therefore be recognized at a great distance. With the exception of crystals of *garnet* and *calcite* which have sometimes crystallized in fissures of hyperite, no foreign minerals occur in this rock; which is more especially the case with regard to the minerals — *olivin* and *zeolite* — characterizing the basalt.

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[1]) A small bed of hyperite is also met with at Middle Hook near Bel Sound. The conglomerates occurring there, belong most likely to the Tertiary formation, and it seems, also, as if eruptions of hyperite, though inconsiderable ones, had existed even in this period. However, the age of the beds of conglomerates etc. at Middle Hook in Bel Sound, for want of fossils, is not quite decided.

[2]) In Parrys Island, on the Western shore of Wijde Bay, and at Cape Staratschin, there occur plutonic rocks *different from the common hyperite of Spitzbergen*.

Real hyperite does not occur on the North coast of North-east Land, nor in the islands more to the North. But already at Depot Point, at the entrance of Brandywine Bay, we meet with a large bed of hyperite surmounted by granite-gneiss, and probably stretching Southward as far as Cape Hansteen and Low Island; the ground of which is in many places paved, as it were, with equally large, sexangular slabs of stone, from $1^1/_2$ to 3 feet [1]) in diameter, and evidently belonging to the uppermost part of a hyperite bed, broken into vertical, sexangular prisms. Most likely this is the same hyperite bed as that which forms the hillock near Aeoli Cross at Sorge Bay, a ramification of which interstratifies the layers at Hecla Hook.

It is, however, only to the South of Hecla Hook, that the hyperite formation attains its complete development. The black masses of rock between Cape Foster and Ice Cape, which there intercept the vast glacier on the North-western shore of Hinlopen, and several mountains in the interior between Sorge Bay and Lomme Bay, consist of hyperite, as far as may be judged by the outward appearance of the mountains. On the Eastern side of Hinlopen Strait, the Hyperite Island separates the limestone beds of Murchison Bay from the fossiliferous strata South of Wahlenberg Bay. At Cape Fanshawe, also, a bed of hyperite surmounts the lower Mountain-limestone strata (Cape Fanshawe strata), and sinks, more to the South, towards the sea; forming, not only some small islands in the middle of Hinlopen, but also two very large mountains on its Western shore, viz: Duym Point and the Alk-range. A hyperite bed of the same age forms the base of Gyps Hook at Ice Sound, and occurs, also, though only to a subordinate extent, on the North shore of Bel Sound. Above this layer, perfectly horizontal strata of the upper Mountain-limestone occur on either side of Hinlopen; and between the upper range of this sedimentary strata, another seam of hyperite intervenes, stretching for miles between

[1]) This ground is already described by Dr. Irving in "A voyage towards the North pole, undertaken 1773 by Constantine John Phipps, London 1774 p. 58.

the stratified layers of limestone and flint, without in the least disturbing them in their position, or at all ramifying itself in transverse veins.[2])

More to the South this seam of hyperite descends to the surface of the sea, forming the Black Mountain in North-east Land, the South Waijgats Islands, and, very likely, several of the mountains on the South-western shore of Hinlopen. On the Northern coast of Stor Fjord it has already descended to the level of the sea, and continues from here Southward, without any further change of level, as far as Thousand Islands; that is, about 100 English miles.

This rock constitutes the base of all the ridge along the North and East coasts of Stor Fjord, and is surmounted by horizontal sandstone strata belonging to the Triassic formation. These strata are, also, covered by a bed of hyperite, from 30 to 70 feet in thickness, forming a most regular, horizontal layer on the upper parts of Mount Edmund and the Western shore of Barentz land and Stans Foreland. Layers of hyperite of the same age occur, also, on the Northern shore of Claas Billen Bay between the sedimentary strata of the Mountain-limestone and the Triassic formation.

Thus, at Spitzbergen, the *layers* of hyperite — as I have often intentionally called them — alternate so regularly with purely sedimentary, fossiliferous rocks, without in the least disturbing their position, without, as far as I could ascertain, having changed their appearance, and without the least traces of transverse veins, that it seems difficult to suppose that the hyperite of Spitzbergen is of a purely eruptive nature, i. e. that it has always erupted in a molten form from the interior of the earth, and that the above-named layers really constitute horizontal veins which have filled up a horizontal fissure, several thousand square-miles in extent. *The seams of hyperite, interstratified between the fossiliferous strata, appear to me rather to constitute deposits of volcanic ashes, or of gravel from destroyed plutonic*

[2]) Transverse veins of hyperite occur in the granite-gneiss, and the Hecla Hook strata at Cape Hansteen, but nowhere in the younger formations.

rocks, which in the course of time, have hardened and become metamorphosed into that anhydrous rock, now called hyperite. Part of the material of the immense fossiliferous strata of flint, occurring in such abundance in the Mountain-limestone, may have originated in a similar manner. The mass of hyperite, however, which underlies the granite-gneiss on the Northern shore of Brandywine Bay, as well as the *mountains* of hyperite on the shores of Hinlopen are probably of a purely eruptive nature.

The hyperite is found cleft into large, vertical, either square or sexangular columns. No satisfactory explanation has hitherto been given of this remarkable phenomenon which is especially peculiar to basalt, and which by some geologists has been regarded as a result of concretionary structure, or even compared to a kind of crystallisation of the whole mass of the rock.* The origin of the basaltic structure, however, appears to lie near at hand, and the phenomenon, though operating on a smaller scale, is a very common one. If, on a warm summer day, we walk across a bed of clay, the surface of which has become dry, we shall often see that the crust of the clay has broken into regular, and mostly sexangular figures. Fissures of the same form may be seen on the marshy plains which are met with at the foot of the mountains in all parts of Spitzbergen. In the middle of summer, when the snow has just melted, they are so very marshy, that in going over them one sinks to the knees in the drenched, sharp stone gravel; but towards autumn they generally become quite dry, and the surface splits into regular figures. *The gradual contraction of a solid mass* evidently constitutes the common cause of the sexangular structure of these so widely different substances.

When the clay or the gravel beds dry, or the plutonic rock cools, a contraction takes place, beginning at the surface, or at the walls of the vein, and gradually perpetuating itself to the interior; the result of which, evidently, is a bursting of the mass. Then the two following conditions *must* be fulfilled.

1:o. The bursting must take place in such a manner, that the resistance it meets with proves a minimum. 2:o. The

particles must not be dislocated to so high a degree as to loosen the upper contracted bed from the lower one that is yet uncontracted. This latter condition is a necessary consequence of the contracting process beginning at a certain plane, and perpetuating itself gradually to the interior of the mass [1]).

If we solve this minimum problem mathematically on the bases of the two conditions above stated, we find that the clefts which arise in a solid mass when it contracts, must necessarily be composed of plane surfaces crossing each other so as to form regular, sexangular columns [2]), and be perpendicular to the surface where the temperature is constant, or parallel with that direction, in which the contraction is progressing. *The columnar structure peculiar to basalt is, thus, a simple consequence of the fact that the bursting, caused by the contraction of the solid mass in cooling, takes place along a system of surfaces where the resistance is a minimum;* and the basaltic structure *has nothing in common with the correctionary structure, or the crystallisation; although the regular form of the basalt columns gives them a certain resemblance to crystalline prisms.*

8. The Miocene Formation.

East of the Grave Hillock, near, or rather beneath, the Frithiof's glacier at Bel Sound, an extensive lowland begins, which, as no outcropping rocks are met with there, prevented me from directly examining the rocks resting on the Jurassic strata of the Grave Hillock. Very likely a continuation of those strata which still occupy Middle Hook at Bel Sound would here have been met with. This high mountain descends in a precipitous slope towards the shore, so that its stra-

[1]) The transversal clefts which often divide the basaltic columns seem to arise from an interruption in the successive contraction, caused for instance, by infiltration of water in the solid, but yet warm rock.

[2]) I am indebted to Professor Lindelöf of Helsingfors for a demonstration, though an indirect one, of this interesting theorem. A complete solution would evidently prove the triangular and qvadrangular, equilateral columns to correspond to *relative minima*, whereas the most common form of sexangular prisms corresponds, as is above mentioned, to *an absolute minimum*.

tified structure is distinguishable at a great distance. On a closer examination it is perceived to consist of alternating layers of qvartzite, limestone, sandstone, conglomerate, and hyperite, dipping 14°—17° S.E. The conglomerate is impregnated with carbonate of lime, and consists of rounded nodules of qvartzite and flint, firmly united by a brown cement, chiefly consisting of flint. The thin layer of hyperite is stratified in a uniform manner between the other beds, in which no traces of fossils are to be found.

These thick layers evidently are, as is seen from the coarse grained conglomerate, mere local formations, the age of which cannot be determined with certainty, they being devoid of fossils. Some of them are probably contemporaneous with the conglomerate beds between Advent Bay and Sassen Bay, constituting the undermost range of that mighty Tertiary formation, the almost horizontal strata of which cover the peninsula between Ice Sound and Bel Sound, and form the shores of Van Mijens Bay, 1000—1500 feet in height. At Coal Mountain there is a fine section of these strata, viz:

a) Black, and very brittle slate, at some places containing nodules of *pyrite*, or of *limestone* enclosing a small kernel of *pyrite*. The strike of these strata which sometimes contain tolerably distinct impressions of plants, and occupy the base of the mountain, is North and South, with a dip of 18° Eastward. A fine section of them may be seen on the steep terrace, several fathoms in height, by which the gradually sloping lowland juts into the sea. Between the black slate, thin beds of more or less compact grey sandstone are often met with, increasing in number the nearer the upper boundary of the black slate is approached; so that these strata gradually pass into:

b) Greyish white sandstone. This sandstone may be divided into two classes, viz: a) The sandstone strata occupying the lower part of the proper Coal Mountain. These strata are remarkable for their greater compactness, and the seams of slate and conglomerate intervening between them.

Some of the beds abound with impressions of fucoïd plants, often more than one foot in breadth. To this measure, also, seem to belong the coal strata of which large pieces are found 500 feet above the surface of the sea. b) Loose, grey sandstone, with scales of talc, and numerous, though indistinct, impressions of small fucoïd plants. These strata, occupying the top of the Coal Mountain and the mountains more to the East in the inner extremity of the bay, are almost horizontal, with a slight dip to the North or Northeast.

Strata, quite similar to these, occur at Mount Sundevall, and at the mountains on the peninsula between Van Mijens Bay and Van Keylens Bay. One looks, however, in vain in these fine strata of sandstone and slate, for any other fossils than the above mentioned impressions of plants which, nevertheless, plainly indicate that these strata are Tertiary.

At Ice Sound the horizontal Jurassic strata are covered by beds of slate and sandstone alternating here and there with thin layers of limestone, and not containing any other fossil animals or plants than some few fragments of dicotyledons, and large, but indistinct impressions of fucus. These Tertiary strata rest on the Jurassic strata which occur at the base of the mountains, and which they greatly resemble in their exterior. They form the whole upper part of the high mountain range stretching from Green Harbour to Sassen Bay, and perhaps separated from the Jurassic strata by the hard beds of conglomerate which, at a height of 500—800 feet above the surface of the sea, between Advent Bay and Sassen Bay, form a perpendicular wall in the steep slope of the mountain. The low headlands, too, on the North shore of Ice Sound are formed of a similar Tertiary sandstone containing thin coal seams and impressions of fucus.

To the same formation, also, probably belong some almost vertical strata of clay-slate from the Western shore of Green Harbour; containing small beds with fossil wood, traces of fresh-water (?) shells, pebbles etc. Yet these beds do not contain any determinable fossils, and it is therefore impossible with

certitude to fix their age, as well as to mark accurately the limit between them and the enveloping Jurassic strata, in which, too, fossils are extremely scarce.

Mr. Blomstrand met with Tertiary strata of great interest at Coal Harbour on the Southern shore of Kings Bay. These strata are, as may be seen from the section on the map, quite folded; so that Tertiary strata seem to underlie layers belonging to the Hecla Hook formation or the Mountain-limestone [1]). They consist of three folded coal-seams, imbedded in sandstone containing leaves of Miocene plants, and surrounded, in descending order, by:

1. Bluish clay-slate with indistinct remains of fishes; belonging either to the same age as the Miocene sandstone, or to the Jurassic formation.

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[1]) The strata of the Mountain-limestone which, at Hinlopen Strait, alternate with plutonic rocks, are almost horizontal; but the Tertiary beds at Kings Bay and Cape Staratschin are, on the contrary, quite folded, notwithstanding no eruptive rock could be discovered in the vicinity, excepting a little vein of diabas (?) at Cape Staratschin. There must, consequently, be some other reason for the folding occurring in these places; and it appears to me that too much importance has been generally ascribed to the influence of the eruptive masses in connection with the folding, upheaval, and dislocation that is almost everywhere observed in the earth's crust. As is the case with innumerable other geological phenomena, this, also, very likely results less from any violent revolution than from some almost imperceptible, but nevertheless continually operating power. The upper part of the earth's crust is, of course, subjected to periodical variations of temperature, which, at Stockholm for instance, at a depth of 70 or 80 feet, rise to 0,01° C. *If the earth's crust were continuous, and the change of volume, caused by these variations of temperature, did not exceed the limits of elasticity of the rock,* they would not exercise any disturbing influence. But as, to a greater or less degree, there are in all mountains fissures and clefts, these will widen in lower temperature, but become narrower as soon as the temperature rises. If, however, as may often be the case, the fissures when enlarged by lower temperature are filled up either with chemical or mechanical sediments, a powerful lateral pressure will naturally ensue when the temperature again rises and extends the rock; and thus every variation of temperature will cause a slight dislocation of the strata. When we consider that this agency is from year to year working in the same direction, and that the extensive movement of many hundred miles of the earth's crust may cause folds only at some narrow spot where the resistance is a minimum, it should not surprise us to find even the newest formations greatly reversed, whereas old formations in the vicinity may be quite undisturbed.

2. Green sandstone resembling the Hecla Hook strata on the South-western shore of Wijde Bay, but probably belonging to the Jurassic formation.

3. Limestone with flint-concretions, probably of the same age as the strata of Cape Fanshawe.

4. Siliceous slate, devoid of fossils, occupying the *higher* mountains on the shore, and the interior of the country; and exactly resembling the Hecla Hook strata at Cross Bay.

The Tertiary strata of Spitzbergen form at many places layers of argillaceous slate and sandstone of more than 1000 feet in thickness; and it might be expected that these fine strata would contain some fossil shells. No remains of Tertiary fossils from the animal kingdom have, however, been met with at Spitzbergen; excepting perhaps some scales of fishes, discovered by Mr. Blomstrand in the slate underlying the coal-beds at Kings Bay. The fossil plants, also, are very scarce and in bad preservation, and we therefore succeeded in collecting only a very small number of tolerably distinct impressions, which have been examined by the celebrated palaeontologist Professor Oswald Heer of Zuerich, who describes them as follows [1]):

"The fossil plants which have been handed to me for examination, have been collected at three different places, viz: Kings Bay (78° 56' N. Lat.), Green Harbour at Ice Sound (78°)[2]), and Coal-mountain at Bel Sound (77° 50'). They are found enclosed in a hard, somewhat coarse grained sandstone which is most unfavorable for obtaining fine impressions of plants, the more so, as it breaks very irregularly. On most of the pieces, the substance of the leaves is still extant, and forms a thin, dark, and sometimes black covering over the stone; on others, it has altogether disappeared, and only the nerves of the leaves are seen impressed in the mass. In consequence of the incompleteness of these impressions, their classification is very diffi-

[1]) Oswald Heer. Om de af A. E. Nordenskiöld och C. W. Blomstrand på Spetsbergen upptäckta fossila vexter. Öfversigt af Kongl. Vetenskaps-Akademiens Förhandlingar 1866. № 6.

[2]) This place is marked on the map with the name *Heers Berg* (Heers Mount).

ult and requires a minute study. I have, however, succeeded in discovering 16 species, which I shall here enumerate:

1) *Gymnogramme (?) Blömstrandi* Hr. n. sp. At King's Bay, in somewhat looser sandstone than that of the poplar and lime-trees mentioned farther on.

A beautiful fern with a pinnated leaf and bipartite leaflets without petioles; resembling *Sphenopteris recentior* Ung. and the still extant *Gymnogramme calomelanos* Kaulf.

2) *Filicites deperditus* Hr. At Bel Sound in the ravines of Coal Mountain.

Only fragments of a petiole and a few leaflets, so that it is impossible to determine them definitely. They are, however, of interest, proving that a large fern with a thick petiole formerly lived here.

3) *Equisetum arcticum* Hr. n. sp. Kings Bay.

Only a few fragments of stalks, and part of a sheath.

4) *Taxodium dubium* Stbg. Sp., Hr. Flora tertiaria Helvetiæ I. p. 49. — At Bel Sound, in the lower strata and the ravines of Coal Mountain.

Two pieces of boughs corresponding fully with those on the European Continent, where this species was widely developed during the Miocene period, and may be traced from the coasts of the Baltic (Samland and Danzig) as far as Sinegaglia in Italy. At Hohen Rhonen, in Switzerland, it was especially plenteous in the lower group of Molass, but still occurs at Oeningen.

5) *Taxodium angustifolium* Hr. n. sp. Bel Sound, upper stratum.

A fine piece of a bough, varying from the former species with respect to its narrower and relatively longer leaves, and which are, also, more widely separated from each other. It may possibly, however, only be a variety of that species.

6) *Pinus polaris* Hr. n. sp. Bel Sound, lower strata.

A species of pine, the leaves of which are united by two and two. The fragments are, however, too incomplete for an exact classification.

7) *Poacites Torelli* Hr. n. sp. Kings. Bay.

Part of a leaf, five millimeters broad, with fourteen nerves extending lengthwise over it; resembling *Poacites lævis* Alex. Br.

8) *Potamogeton Nordenskiöldi* Hr. n. sp. Bel Sound; the leaf occurring most commonly.

An elongated, oval, thin leaf with a long stalk and the nervure of a *Potamogeton;* and most resembling *P. natans* L. or *P. fluitans* Roth.

9) *Populus Richardsoni.* Hr. Bel Sound; lower stratum.

A poplar species, nearly related to *Populus tremula* L., which I have shown also to occur in the Miocene formation in North Greenland and on the Mackenzie River.

10) *Populus arctica* Hr.? Kings Bay.

Only the base of a leaf, corresponding, however, with leaves from North Greenland and the Mackenzie, where this species once was common, and was met with in numerous forms.

11) *Salix sp.?* Bel Sound.

An indistinct fragment of a leaf, appearing to belong to a *Salix.*

12) *Alnus Keferstcini* Goepp. Bel Sound, lower stratum.

Two fragments of leaves, corresponding with this widely spread Miocene plant, but especially with leaves from Samland or the lignite beds at Danzig. Here, as well as in Iceland, well preserved cones of this shrub were met with.

13) *Corylus Mac Quarri.* Forb. spec.? *C. grosse-dentata* Heer. Flora tertiar. Helvet. II. p. 44. Bel Sound; lower stratum.

Several fragments of leaves without any margins. The nervure, however, corresponds tolerably with that in leaves of the above named hazel, such as it is obtained from North Greenland, Iceland, and numerous places on the European Continent.

14) *Fagus Deucalionis* Ung. Bel Sonnd.

Only the fragment of a leaf has been met with; but it so well corresponds with the leaves of this Miocene beech, as

it has been found in Greenland and numerous places in Germany, that it must be referred to this genus.

15) *Platanus aceroides* Goepp. Heer Flora tertiar. Helvetiæ II. p. 70. Green Harbour.

A specimen of a large digitated leaf which, although its margin is defective, nevertheless with regard to its yet extant parts, completely corresponds with *Plat. aceroides*. Its form and nervure undoubtedly class this plant under the tribe *Platanus*; and most likely it belongs to *Pl. aceroides* occurring in the Molass of Switzerland and Upper Italy.

16) *Tilia Malmgreni* Hr. n. sp. Kings Bay; in a hard sandstone.

A remarkably large leaf of a lime-tree, resembling *Tilia americana* L., but having smaller indentations. Although the right side of this leaf is almost destroyed, it may, nevertheless, be traced that three principal nerves, together with the middle nerve, there proceed from the base of the leaf; but only two from the left side. This important sign, together with the greatly ramified and opposed secondary nerves running parallel with the margin and the serrated edge, prove it to be a leaf of a lime-tree. This is confirmed by a specimen found at Bel Sound, and containing fragments of a leaf and a branch bearing either flowers or fruit, which, though indistinct, are nevertheless recognizable. This branch consists of several somewhat long and clusterlike stalks, on one of which there is a little oval figure — whether a bud or young fruit, cannot be decided.

Although the number of fossil plants from Spitzbergen is so small, they yet furnish us with material from which important conclusions may be drawn. Among these I will name the following:

1) The stratum in Coal Mount, containing leaves of trees, is a *freshwater formation*. This seems to be proved by the above mentioned genus *Potamogeton*, such large- and broad-leaved *Potamogetons* never occurring in salt water. The leaves found in this stratum can, consequently, not have been brought hither by the sea; but must have grown on the spot, or at least

in the vicinity. The same may, undoubtedly, be said with regard to the land plants from Green Harbour and Kings Bay. Hard seeds, (of the *Entada* for instance), and wood may, it is true, be borne by ocean currents from far distant parts; but this is not the case with leaves, as they would be dissolved during so long a transit. The marine animal fossils met with on Coal Mount, at Bel Sound, must accordingly belong to other strata.

2) The sandstones of Coal Mount, containing remains of pines and other trees, as well as those from Green Harbour and Kings Bay, date from the Miocene period. Of the eleven species from Bel Sound there are five, namely, *Taxodium dubium*, *Populus Richardsoni*, *Alnus Keferstéini*, *Corylus Mac Quarri*, and *Fagus Deucalionis*, which have been found in the Miocene; and the rest, as far as they can be classified, are most nearly allied to species from the same period.

From Green Harbour, I have seen but one species that could be classified *(Platanus aceroides)*, but that one characterizes the Miocene formation.

Only one species from Kings Bay *(Populus arctica)* has been met with at any other place; but in consequence of bad preservation its classification is not fully to be relied upon. Notwithstanding, we may regard the hard sandstone at Kings Bay, containing leaves of this poplar and the above mentioned lime-tree, as belonging to the Miocene period; for, excepting that formation, the Cretaceous period would be the only one to be thought of; in this, however, no leaves of lime-trees have ever been met with.

The *Gymnogramme*, *Equisetum*, and *Poacites* from Kings Bay are contained in somewhat looser sandstone, possibly belonging to another formation; which cannot be fully ascertained from these plants. *Equiseta* occur in the most heterogeneous formations, and the fern, too, belongs to forms which are widely spread in formations from different geological periods.

3) During the Miocene period the climate of Spitzbergen must have been much warmer than it is at present. The occurrence of large leaves of trees corroborates this supposition; but

still more so, a comparison between these and the nearest still extant species related to them. The genera *Pinus, Equisetum, Potamogeton, Populus, Salix, Alnus,* and *Corylus* still extend as far as to the Arctic zone; but, at present, the *Salix,* alone, is found higher than 70° N. lat., and even at Spitzbergen; while the Northern limit of some of the other genera does not extend farther than 58° or 62° lat. There are, besides, several species, the living relatives of which do not reach the arctic circle. The *beech (Fagus silvatica)* will not live in Scotland, even when cultivated, higher than 57° N. Lat.; and on the Norwegian coast, so favoured with reference to its climate, it does not extend beyond 60° 31′ N. Lat. (Alvesund); whereas the Miocene species at Spitzbergen is met with at even 17 degrees of latitude nearer to the Pole. — With reference to *Tiliæ,* the Northern limit of the American species is at Lake Vinipeg (50½° N. Lat.), and there it only occurs in the form of a shrub; in Europe, the small-leaved lime-tree *(Tilia parvifolia)* extends as far as 62° on the Northern coast of Norway, and it is even cultivated on an especially favorable spot, at 63° 42′. At Spitzbergen we, however, find a lime-tree as far North as about 79° N. Lat.; most resembling, on account of its large leaves, the *T. americana.* — The species of the genus *Taxodium* thrive best in the marshy tracts of the Southern States of America, especially between 31 and 32° N. Lat.; but they are also met with in Kentucky and Virginia as far as the Delaware (consequently at 40° N. Lat.). When cultivated in Europe, however, they endure the clime of a much higher latitude. Thus, we find them in the gardens of Switzerland, in the environs of London etc.; but in Germany their cultivation does not appear to succeed beyond 53° L.

These taxodiums, large-leaved lime-trees, platanes, and beeches demand for Spitzbergen, during the Miocene period, a mean summer temperature of 14 or 15° C. The South of Sweden and Norway (Christiania for instance, which has a mean temperature of 5,3° C, during the year, and 15,4° during the summer) probably now possesses a climate similar to that which prevailed during the Miocene period at 78° N. Lat.; because, here,

besides a poplar, the large leaved lime was also found. Kings Bay is situated about 32° more Northward than Middle Switzerland (47° N. Lat.) and would therefore have had a temperature of about 16° Celsius lower than Miocene Switzerland, for which, by the combination of numerous phenomena I have calculated a mean temperature of 21° C. (Compare: Klima- u. Vegetations-Verhältnisse des Tertiärlandes p. 133.) We hereby obtain a decrease of temperature for each degree of latitude Northward, of 0,5°. At present, the difference of temperature, if we make a reduction for the mean temperature of Switzerland to the level of the sea, constitutes 20,6° C.; which makes 0,66° C. for each degree of latitude. The decrease of temperature towards the North is, consequently, at present greater than it was during the Miocene period. Probably, however, the difference of temperature in both these countries was then still less than we have assumed above; a comparison between the present Flora of Spitzbergen and Switzerland, and the Miocene Flora, points to this. Of the 93 phanerogamic plants which, according to Dr. Malmgren, now occur at Spitzbergen, nearly one third are also met with in Switzerland. Only three species of these, however, are found on the lowland; all the rest being first met with on the Alps, and the greatest number at considerable heights. With respect to the Miocene plants of Spitzbergen, nearly one half were also found in Switzerland or adjoining countries; and the other half consists entirely of species that appear to belong to a similar climate. There is not one among them that could correspond with purely Alpine or high Northern types. This arctic Miocene Flora comprehends such species of our Miocene Flora as correspond with the temperate zone. A greater similarity than now must, therefore, have existed at that period; as a larger number of species were spread from our degree of latitude up to high arctic regions, than is at present the case.

We may assume that the places at Spitzbergen, marked above, where the taxodium, beech, plane-tree, and lime were found, constitute their Northern boundary; but with respect to firs, alders, and poplars, this is certainly not the case, as the

still extant representatives of these tribes are yet found, 4–10 degrees more to the North, than the before named tribes. They must therefore, undoubtedly, during the Miocene period, have had a far greater extension to the North, even to the Pole itself, provided a mainland then existed there; and we may, too, with a great degree of probability, name the trees which composed the woods of that country. They must have been species of pines and poplars, as we are able to refer to the occurrence of such not only at Spitzbergen, but also in North Greenland and Arctic America. They are also met with, here, in such a variety of species, that we cannot doubt of their farther extension from this point towards the North; which will be more fully represented in my work: "Die fossile Flora der Polarländer." This work will also contain figures and minute descriptions of the plants of Spitzbergen here mentioned."

The strata, most important from an economical point of view, occurring in the Miocene formation of Spitzbergen, are undoubtedly the coal-seams that have been met with at various parts of these islands. Already, at the time when the whalers visited Spitzbergen, they used, according to Scoresby, to anchor at Kings Bay in order to supply themselves with coal for fuel. Keilhau mentions among imports from Spitzbergen to Norway sixty "tunnor" of coal. All the older whalers speak of places where coal is found either in the rocks, or in loose pieces carried down by the glacier-streams. During the French Expedition, Robert examined the coal-bearing layers at the inner part of Recherche Bay and van Keylens Bay. According to his not very clear description these strata rest on greatly folded strata of limestone loaded with fossils of the genera *Productus* and *Spirifer;* while the beds of sandstone and slate containing coal are tolerably horizontal, and contain no other fossils than indistinct impressions of plants. As is above mentioned, Mr. Robert among these, also, enumerates impressions of *Sigillaria* and *Lepidodendron*, although the beds on the shores of Van Keylens Bay are cotemporary with the undoubted Tertiary strata at

Coal Mount. The coal-beds on Beeren Island are, evidently also, Tertiary; and this, too, is possibly the case with respect to the coal-beds discovered by Parry, M'Clintock, and others, in the North American Polar zone.

Besides Bel Sound and Kings Bay, coal has been met with at the following places at Spitzbergen:

Green Harbour in Ice Sound. At the foot of Heers Mount, South of the deep valley descending to the East shore of Green Harbour, Mr. Blomstrand met with coal at the height of about 700 feet above the surface of the sea, just below the upper projecting layer of sandstone. The thickness of the coal-bed could not be ascertained. In the fine grained sandstone containing mica, besides several indistinct remains of plants, there was also found a distinct leaf of *Platanus aceroides*.

Advent Bay. Between Green Harbour and Advent Bay, coal-seams are here and there met with in the mountains. About half a mile before reaching the outlet of Advent Bay, the perpendicular sandstone rock which is bare, and unincumbered by gravel, juts almost straight into the sea; and in it Mr. Blomstrand discovered several coalbeds, the undermost of which, having a thickness of about two feet, lay, at low water, three feet above the surface of the sea, and was nearly horizontal. Parallel with the main layer, and from 4 to 10 feet above it, three or four minor coal-seams could be observed.

The Northern shore of Ice Sound. The Spitzbergen whalers state that considerable beds of coal, though difficult of approach, occur in the mountains inside the glaciers between Cape Boheman and Safe Haven. In 1864, I myself met with a small coalbed on one of the little islands (Coal Islands) South of Cape Boheman. The coal was here surmounted by hard sandstone similar to that at Coal Mountain, and containing impressions of fucoïd plants.

The Eastern part of Spitzbergen. From Black Point, East of Dove Bay, Mr. Lamont brought home fossil trees with coal attached to them; and Spitzbergen whalers state that detached pieces of coal are found in abundance on the shore of Walter

Thymens Strait. Besides this, Lamont met at Black Point with beds containing fossils of the species *Nucula* and *Aviculopecten*. Tertiary and Jurassic strata appear, also, to occur on the Eastern shores of Spitzbergen.

On the Northern shore of the peninsula West of Recherche Bay there is found a loose sandstone with very indistinct impressions of plants, and containing rounded pieces of coal. These are remarkable for the small nodules of yellow amber which they enclose. Coal with fossil resine is, also, met with among the gravel on the shore farther to the interior of the bay. It is uncertain whether these layers which evidently have originated from the crushing of the Miocene coalbearing beds, were deposited during the Tertiary period, or whether they are Post-Tertiary. The origin of the coal however is, no doubt, Tertiary; and the fact of its containing resine throws an important light on the character of the vegetation that gave origin to the arctic coalbeds.

The Recent Period.

Spitzbergen is, at present, almost entirely covered with glaciers. Thick ice beds, immense moraines, glacial clays, and other glacial deposits occupy by far the greater part of the surface of the country. A complete account, therefore, of all the phenomena connected with this formation ought, properly, to form the conclusion of this Sketch of the Geology of Spitzbergen. Professor Torell's first Expedition to Spitzbergen in 1858 was also to a great extent induced by a desire to obtain the solution of certain questions connected with the European Glacial Period, through immediate observations in a country still overwhelmed with ice. Both during this and several other expeditions to Spitzbergen, Iceland, and Greenland, as well as during extensive travels in Europe, Mr. Torell, accordingly, devoted his attention to researches of this kind; and we may, as a result of these comprehensive investigations, expect a complete monograph of that important period. The less complete descrip-

tion of the glacial period of Spitzbergen which I might here give, may consequently be omitted.

The following table affords a view of the strata observed by us at Spitzbergen:

I.	*Crystalline rocks.*	a) Granite and gneiss.
		b) Vertical strata of mica and hornblende schist intersected by beds of qvartzite, crystalline limestone, and dolomite.
II.	*Hekla Hook formation.*	a) Strata, at least 1500 feet in thickness, devoid of fossils; consisting of red and green clay-slate, grey, white-veined limestone, and qvartzite.
		b) Red, ferruginous slates and conglomerates, devoid of fossils; of less extension, and unascertained thickness.
III.	*Mountain-limestone.*	a) Ryss Island limestone, or rather dolomite, devoid of fossils, and intersected by beds of qvartzite and flint. Thickness about 500 feet.
		b) Cape Fanshawe strata; containing corals. 1000 feet at the most in thickness.
		c) Layers of hyperite.
		d) Upper range of the mountain-limestone, consisting of calcareous sandstone, limestone, gypsum, and flint; abounding in fossils, and rising to 2000 feet in thickness. Between the sedimentary layers in this measure extensive hyperite seams also intervene.
		e) A very extensive and regular bed of hyperite, stretching from Mount Edlund to Thousand Islands.
IV.	*Triassic formation.*	Black, bituminous slate, hyperite beds limestone, coprolite, beds, and sandstone, with

rests of *Saurians, Nautilus, Ammonites*, etc.; about 1500 feet in thickness.

V. *Jurassic formation.* Clay-slate, limestone, and sandstone abounding in pyrites, and intersected by a small seam of hyperite. At Agardh's Mount the thickness amounts to 1200 feet.

VI. *Miocene formation.* A freshwater formation; rising in Bel Sound to 1500 feet in thickness, and consisting of conglomerates, clay-slate, limestone, and sandstone; almost devoid of animal fossils, but containing coal-seams, and fine impressions of plants.

VII. *The Recent period.* Glaciers and deposits belonging to the glacial period.

Each of these strata constitutes a page in the geological history of the Polar regions; and although the defects are too great to allow us to form a complete idea of the changes effected in that part of the earth's crust, yet the whole, from the isolated position of Spitzbergen in the vicinity of the Pole, may afford many important additions to the history of our globe.

As in all other parts of the earth's crust, so also at Spitzbergen, land and sea have many times alternated. The lower range of the Hecla Hook formation, from its fine-grained argillaceous schists, is evidently a salt-water formation, deposited at a great distance from land. The upper range, on the other hand, is a strand deposit, as is evident from the abundance of conglomerates consisting of rolled pieces of a qvartzite and an argillaceous slate quite resembling specimens of corresponding rocks from Hecla Mount. A considerable continent must at that period have existed in these regions.

The Mountain-limestone at Spitzbergen is a salt-water deposit; and as is seen by the absence of conglomerates, it is deposited at a considerable distance from land. We may, however, infer from the layers of gypsum along the shores of Klaas Billen Bay that during this period, too, a closely surrounded bay must have existed in these parts, which subsequently became dry after having been completely separated from the sea. Powerful erup-

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tions of hyperite and depositions of volcanic ashes and gravels several times took place during that period, without, however, causing any essential interruption in the existence of animal life.

Both the nature of the rocks, and the fossils indicate that the upper range of the Triassic formation was deposited near land; which seems to have been the case also with part of the Jurassic formation containing masses of pyrites. The materials of the sandstones belonging to these formations must have been taken from some completely destroyed layers, any traces of which we at least were not able to discover in the yet existing rocks. During these periods, also, powerful eruptions of hyperite took place; so that thick deposits of volcanic ashes, transformed into hyperite, interstratify the sedimentary layers.

The Miocene formation at Spitzbergen is, as we have mentioned above, a fresh-water formation and a vast continent probably then existed in these regions.

All the fossils that have been met with at Spitzbergen indicate that the present distribution of climate on the earth's surface dates from the most recent geological period; and that the idea we at present entertain of the contrasts of Equatorial and Polar climates, is not even applicable to the periods directly preceding the present age.

The large corals (for instance we brought one home from Klaas Billen Bay, that measured nearly two feet in diameter), and the large species of *Productus* and *Spirifer*, from the Mountain-limestone, evidently lived in a warm, perhaps even a tropical climate; and from the remains of *Ammonites* and *Saurians* in the Triassic and Jurassic formations, as well as the impressions of *Platanus* and *Taxodium* from the Miocene period, we may infer that the climate only gradually changed, so that it was still mild, and favorable to a luxurious forest vegetation, during the Tertiary age. Our investigations of Spitzbergen, however, throw no light on the transition from the Miocene period to the Glacial formation of the present time, or on the nature of the animals and plants that lived in the vicinity of the

Pole during the Pliocene and the European Glacial periods[1]). We did not there meet with any deposits that might be regarded as a link between the Tertiary strata at Bel Sound and the present age. Evidently the strata deposited during this period, were ground down and carried away by the glaciers. A slight indication of the change that has taken place, is, however, supplied by a subfossil shell, found by Mr. Torell and Mr. Malmgren on the shore of Hinlopen Strait, as well as by Mr. Blomstrand in an especially interesting layer of earth on the shore of Advent Bay. This shell, *Mytilus edulis*, at present occurs in abundance along the Scandinavian coasts; but does not any longer inhabit Spitzbergen. At least the zoologists of the Spitzbergen Expeditions were not able to obtain a single living specimen of it, in the dredgings undertaken *by several boats almost every day* during three summers, in the Bays and along the shores of Spitzbergen. Immense numbers of this shell still, at Tromsö and Hammerfest, inhabit the shallows and banks laid bare by the tide; and, at Spitzbergen, it probably became extinct when the coasts were overwhelmed with glaciers, and great blocks of ice began to drift along its shores, crushing and extirpating all animal life to a certain depth.

We may assume, from many circumstances, that the layers with *Mytilus* at Spitzbergen are a great deal younger than the glacial beds in Scandinavia; so that these Northern tracts would have been comparatively free from ice during the European Glacial epoch. *It seems, also, as if Spitzbergen seldom during former geological epochs was covered by glaciers; at least we in vain, in the various rocks of that island, searched for stones furrowed by the action of ice, or boulders, or other beds resembling the glacial deposits of the present age.*

[1]) If Pliocene or Post-Tertiary beds exist at Spitzbergen, they most likely are to be met with either in the interior of the peninsula between Ice Sound and Bel Sound, the only tract of any extent uncovered by ice, or on the Eastern shore of Barents Land and Stans Foreland. A complete exploration of the first named place especially, would be of great interest Traces of Post-pliocene (?) beds were found by us, as is above mentioned, on the shore South of the entrance to Bel Sound.

Remarks on the enjoined maps.

Map I. A photolithographic copy, on a reduced scale, of an anicent dutch map of Spitzbergen by Commodores Giles and Outger Rep.

Map II. A geological map of Spitzbergen on a scale of 1:1,000,000; with eight sections.

The sections 1—6 and 8 are drawn on an approximate scale of 1:100,000 in a horizontal, and 1:10,000 in a vertical direction; *but it is to be observed that the coal-seams and the hyperite beds are, in order to render them more distinct, delineated somewhat too large.* For the section 7, Blomstrand seems to have employed a scale of 1:500.

1. Section of the Northern part of Hecla Hook.

2. Section of the Northern shore of Murchison Bay, from the longitude of 18° *Eastward.*

3. Section of the headlands extending from Northeast Land, Northward.

4. Section of the Northern or rather Northwestern shore of Klaas Billen Bay; from latitude 78°33 and longitude 16°18 to Cape Thordsen.

a. North of the river, or the Reindeer valley, Middle Hook.

b. South of the river, Saurie Hook.

c. Low terrace of great extent, covered with rocks and boulders of hyperite.

d. Flintbeds with *Productus*, overlying beds of grey gypsum.

e. Skans Mount.

f. Rocks polished by ice, consisting of red and grey striped slate, and covered with a grey limestone, the upper beds of which contain a great number of corals.

5. (Blomstrand.) Section of the shores on both sides of Green Harbour. It is, however, uncertain whether the Tertiary strata West of Green Harbour *cover* the Jura strata, or whether they are *encompassed* by a fold of them.

6. Section of the Northern shore of Van Mijens Bay, from Coal-Mount *Westward*

a. The Grave Hillock, since the winter of 1861—1862 covered by a mighty glacier.

b. Beds of black clay-slate, with seams of sandstone, containing impressions of Miocene plants.

c. A narrow coal-seam.

7. (Blomstrand.) Section of the coal-beds at Kings Bay (lat. 78°16'; longit. 12°).

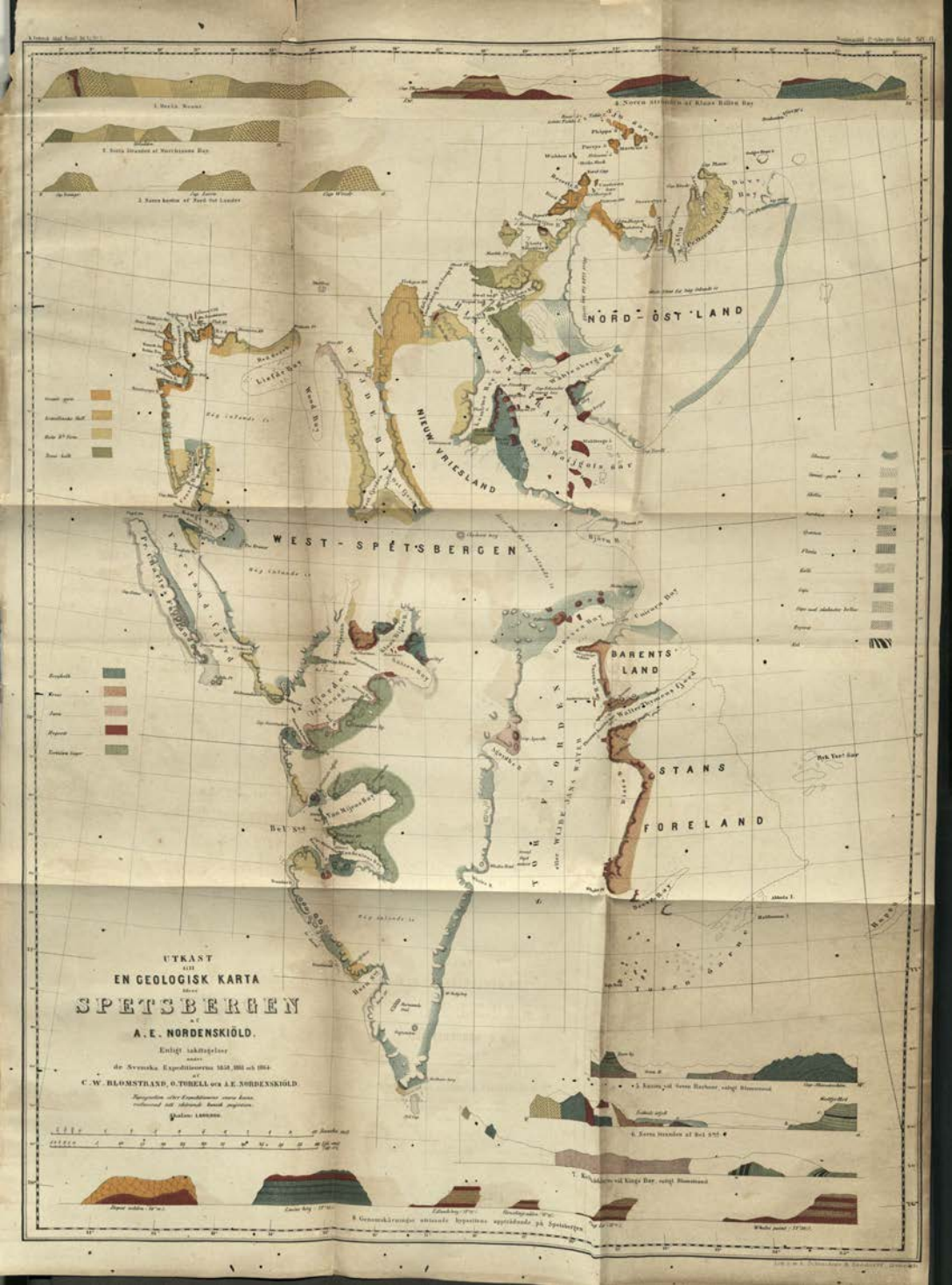
a. Sandstone with Miocene plants.

8. Sections showing the extent and *stratification* of the hyperite beds at Spitzbergen.

Glossary of the Swedish terms employed in the Geological Map.

Berg, berget. Mount.
Bergkalk. Mountain-limestone.
Drifvedsstranden. Driftwood-shore.
Fjäll. Mount.
Flinta. Flint.
Gips. Gypsum.
Gips med alabaster-bollar. Gypsum with nodules of alabaster.
Hög isvägg. High ice-wall.
Istjäll. Glacier.
Kalk. Limestone.
Kristallinisk skiffer. Crystalline schist.
Kol. Coal.
Nord. North.
Nordost-land. Northeast Land.
Ost. East.
Ryssökalk. Ryss Island Limestone.
Sandsten. Sandstone.
Sju öarne. Seven Islands.
Syd. South.
Tertiära lager. Tertiary beds.
Tusen öarne. Thousand Islands.
Udde. Point.
Öfver 2000 fot hög inlands is. Inland ice, more than 2000 feet high.
Ö. pl. ör. Island.

Afbildning i förminskad skala af ett gammalt sjökort öfver Spetsbergen.


NORD-ÖST LAND
NIEUW FRIESLAND
WEST-SPETSBERGEN
BARENTS LAND
STANS FORELAND
UTKAST
TILL
EN GEOLOGISK KARTA
ÖFVER
SPETSBERGEN
AF
A. E. NORDENSKIÖLD.
Enligt iakttagelser
under
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af
C. W. BLOMSTRAND, O. TORELL och A. E. NORDENSKIÖLD.
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